

Leave the expressway or not? Impact of dynamic information

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Abstract This study investigates drivers' diversion decision behavior under expressway variable message signs that provide travel time of both an expressway route and a local street route. Both a conventional cross-sectional logit model and a mixed logit model are developed to model drivers' response to travel time information. It is based on the data collected from a stated preference survey in Shanghai, China. The mixed logit model captures the heterogeneity in the value of "travel time" and "number of traffic lights" and accounts for correlations among repeated choices of the same respondent. Results show that travel time saving and driving experience serve as positive factors, while the number of traffic lights on the arterial road, expressway use frequency, being a middle-aged driver, and being a driver of an employer-provided car serve as negative factors in diversion. The mixed logit model obviously outperforms the cross-sectional model in dealing with repeated choices and capturing heterogeneity regarding the goodness-of-fit criterion. The significance of standard deviations of random coefficients for travel time and number of traffic lights evidences the existence of heterogeneity in the driver population. The findings of this study have implications for future efforts in driver behavior

modeling and advanced traveler information system assessment.

Keywords Travel decision · Mixed logit · Travel time · Repeated choices · Variable message sign · Stated preference

1 Introduction

The effectiveness of advanced traveler information systems (ATIS) depends highly on travelers' behavior in response to real-time information. It is well recognized that it is important to identify the factors that influence travelers' decision behavior under ATIS [1–29]. Research results in this challenging field can facilitate better investment, design, and operation of ATIS technologies.

Internationally, variable message signs (VMSs), a common ATIS technology, has been widely used to manage the traffic on urban expressways with high demand. In developed countries, many metropolitan cities such as Paris (France), Munich (Europe), Chicago (USA), and Tokyo (Japan), use VMS to enhance expressway management. In China, big cities such as Shanghai, Beijing, Guangzhou, Hangzhou, Ningbo, Chengdu, and Suzhou have installed a lot of VMS on urban expressways. In the real world, VMS information can be descriptive (e.g., statements of traffic conditions) or prescriptive (e.g., suggestions on what to do). It can be quantitative (e.g., travel time estimate, estimated delay, and length of queue) or qualitative (e.g., warnings of incidents, statements of level of service, and bad weather alerts).

However, the existing expressway VMSs usually can only provide information about expressway conditions and do not provide information about local streets (e.g., parallel

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arterial roads) due to technological reasons and/or institutional barriers (e.g., expressways and local streets are operated by different agencies). This may limit their effectiveness in diverting urban expressway traffic to local streets, since travelers are not given real-time information about local streets. In Shanghai, as the Traffic Police Department reported on newspapers, many outbound elevated roads (urban expressways) connecting the downtown and the suburb often have big delays, and their travel time is surprisingly much longer than the travel time of parallel arterial road under them during some traditional national holidays (e.g., the Qingming holiday during which people go to big cemeteries in neighbor cities to hold a memorial ceremony for their families they lost). This situation is partially due to the fact that drivers are not so confident that they will be better off after they divert to a local street since they are not given any real-time information about alternate routes. A feasible way to help drivers make more informed diversion decisions and alleviate expressway congestion is to update the existing expressway VMS service in Shanghai. In this context, Shanghai is planning to provide a new expressway VMS service which gives travel time information about both an urban expressway route and a competitive alternate arterial road route.

This study, therefore, will investigate the impact on drivers' diversion decision behavior of the new expressway VMS information that provide travel time of both an expressway route and a local street route in the context of Shanghai, China. Such expressway VMS was rarely addressed in the literature to the best knowledge of the authors.

In previous studies, many researchers used stated preference (SP) data from questionnaire surveys to model drivers' response behavior, e.g., [5–16]. Some other studies used SP data from travel simulator experiments (e.g., [17–25]). Others used revealed preference (RP) data to model drivers' response behavior (e.g., [26–29]).

When new ATIS features or options are to be addressed which do not exist in the market, only SP survey is available. In a typical SP survey, each respondent responds to several hypothetical scenarios, thus, the issue of correlations among repeated observations from the same respondent arises. This issue should be addressed carefully when developing driver response models [3, 18].

Despite the large number of publications on travel behavior under ATIS, relatively fewer studies accounted for correlations among repeated observations; see, for example, [3] for a recent review. With the increasing popularity of simulation-based estimation, panel data models that address repeated observations are gaining more attention. Methodologies that have been applied to address repeated observations include mixed logit models (e.g., [19, 23]), random effect models (e.g., [14, 29]),

multinomial probit (e.g., [13, 18]), normal mixing distributions (e.g., [6]), generalized estimating equations (e.g., [5, 15]), and mixed linear models (e.g., [25]).

It is also desirable that a response behavior model is capable of capturing the heterogeneity in drivers' taste (preferences) [4, 19]. In the context of this study, the possible preference variations across individuals regarding travel time information and other alternative attributes will be appropriately addressed.

The mixed logit model provides the flexibility to cope with these above issues. In mixed logit models, an additional error term is added to the utility specification. The additional term captures heteroscedasticity among individuals and allows correlation over alternative and time. Recent advances in simulation-based estimation procedures make the mixed logit model more computationally feasible and attractive. This study, therefore, will use the mixed logit model to account for repeated choices and capture the heterogeneity of drivers' decision behavior.

Given the above context, two distinguishing features of this study are: (1) A mixed logit model is developed that addresses correlations among repeated choices from the same respondent and capture the heterogeneity in drivers' value of certain alternative attributes (i.e., travel time and number of traffic lights); it is also compared with the conventional cross-sectional logit model. (2) The type of expressway VMS information addressed by this study is travel time of both an expressway route and a local street route. Such expressway VMS information was rarely addressed in the literature.

This study will obtain a preliminary understanding of drivers' diversion decision behavior under Shanghai's new expressway VMS information and will have implications for further modeling efforts in drivers' decision behavior under ATIS.

The rest of this paper is organized as follows: First, the design of SP survey and collected data are described. Next, the mixed logit model for drivers' diversion decision behavior under VMS is developed and compared with the conventional cross-sectional logit model. Finally, concluding remarks are given.

2 Methodology

2.1 Survey method

Expressway VMS has been used for many years in Shanghai [30, 31]. However, they currently do not provide traffic information about local streets. Thus, only SP behavioral data can be collected by this study.

The SP experiment was conducted based on a hypothetical trip that is outlined by a dotted rectangle on the

Shanghai urban expressway network map shown in Fig. 1a. Symbol “*O*” means trip origin and symbol “*D*” means trip destination. Trip origin is Pudong International Airport, and trip destination is Wujiaochang central business district. The travel scenario contains an untolled expressway route and an alternate arterial road route (depicted in Fig. 1b). The VMS before the diversion point provides travel time of both the expressway and the arterial road.

Respondents were required to assume that they were making a trip during the off-peak period in a weekday afternoon. Respondents were told that once they diverted to the arterial road it would be impossible to get back on the expressway. The expressway is the usual route from Pudong Airport to Wujiaochang. The alternate arterial road route is an imaginary route. The arterial road route can be deemed as an alternate route that a real-world VMS-based ATIS recommends to drivers [5, 25]. Thus, our SP settings are reasonable, though the employed network at first sight seems simple. Normal travel time for the expressway is thirty minutes. A similar SP experiment design was adopted by Abdel-Aty et al. [6] which also specified a hypothetical journey consisting of a primary route and an imaginary alternate route.

The VMS messages designed in the SP survey have a wording style similar to the real-life Shanghai expressway VMS and consist of two parts: (1) travel time of the expressway and travel time of the arterial road and (2) cause of expressway delay (Fig. 1b).

The factors controlling the SP experiment are the following attributes: Travel time of the expressway route, Cause of expressway delay, and Number of traffic lights on the arterial road.

The attribute values are specified based on discussions with Shanghai expressway network traffic management center operators and VMS messages records. For a

30-minutes-around off-peak expressway journey, the range of [0, 10] minutes is considered reasonable for expressway delays by traffic management center operators. To this end, expressway travel time takes two values: “35 min” (i.e., a 5-min delay) and “40 min” (i.e., a 10-min delay). Cause of expressway delay contains two levels: “Congestion” and “Accident.” The number of traffic lights on the arterial road takes two values: “10” and “20”, with consideration of typical spacing of traffic lights in Shanghai.

The complete factorial design [32] was used to produce eight ($2 \times 2 \times 2$) SP choice scenarios which are in accordance with eight questions. In all SP scenarios, travel time of the local street route remains to be thirty minutes.

Given a specific VMS message, a respondent was asked to choose between “continue via expressway” and “divert to the arterial road.”

2.2 Data collection and descriptive analysis

An SP questionnaire survey was conducted in April 2007 in the parking lot of Shanghai Pudong international airport. The collected data consisted of two parts: (a) driver characteristics, such as, gender, age, years of driving experience, frequency of using expressway, and driver type; (b) diversion decisions under VMS.

A total of 171 drivers participated in the survey. The experimenters read questions to respondents and recorded answers of the respondents. After removing the respondents, not fully completing the questionnaire, the data set available for model development contains 140 drivers and 1,120 (140×8) choice observations in total.

Table 1 shows driver characteristics of the sample.

In the sample, 74.3 % of respondents are male drivers. The majority of the sample is frequent expressway users (49.3 % + 23.6 %).

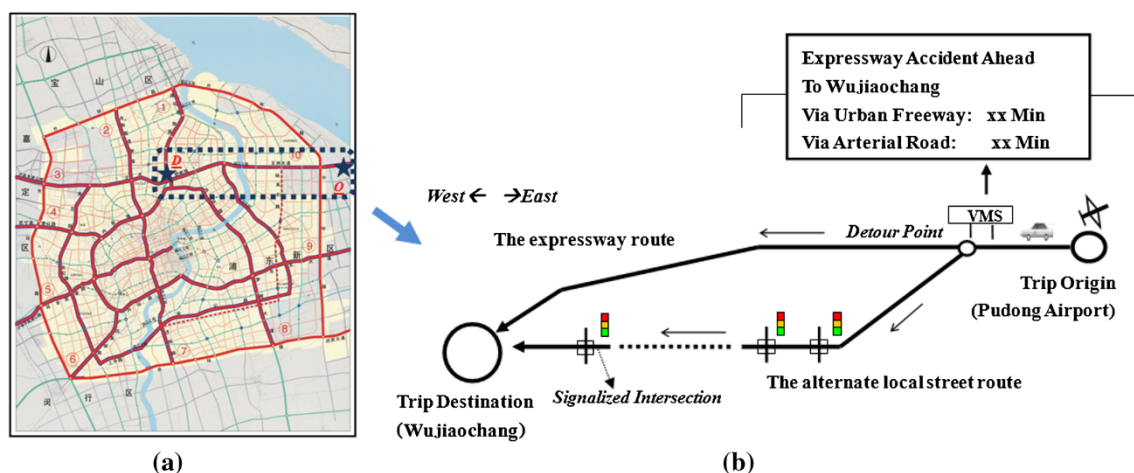


Fig. 1 SP survey. **a** Expressway network in Shanghai, **b** travel scenario

Table 1 Driver characteristics of the sample

Attribute	Range	Percentage (%)
Gender	Male	74.3
	Female	25.7
Age (years)	20–29	24.3
	30–39	41.4
	40–49	25.0
	50–64	9.3
	>64	0.0
Years of driving experience	<2	6.4
	2–5	41.4
	6–10	37.1
	>10	15.0
Driver type	Private car	42.1
	Employer-provided car	35.0
	Taxi	22.9
Expressway use frequency	Almost every day	49.3
	2–3 days per week	23.6
	Seldom	27.1

“Private car” is owned by a driver himself/herself

“Employer-provided car” is not owned by a driver but assigned by his/her employer for business purpose

In China, a person at a high hierarchy level in a company or governmental agency is allowed to use a car owned by his employer. The high proportion of employer-provided car drivers does reflect Shanghai situation.

The seemingly high proportion (22.9 %) of taxi drivers accords with TMC officials’ suggestion that the proportion of taxi vehicles on the expressway originating from Pudong airport typically ranges from 10 % to 50 % varying with time of day. This estimation was also justified by real-world observations. Thus, taxi drivers are included in model estimation.

Overall, in case of expressway delays, the diversion (i.e., choosing the local street) percentage for all the eight SP choice scenarios is 47.3 %. That means almost half of the survey respondents stated their intention to divert while encountering delay on their original urban expressway route.

At the scenario level, observing diversion percentage variations among scenarios is interesting and insightful. For example, under Scenario 2 and Scenario 6, over 70 % (72.1 % and 70.7 %, respectively) of drivers express their intention to divert to the local street, presumably because the travel time saving from diversion is 10 min, and the number of traffic lights is only 10. Conversely, Scenario 3 and Scenario 8 only cause a bit more than 20 % (22.1 % and 23.6 %, respectively) of drivers to intend to divert, possibly because travel time saving from diversion is only 5 min but the number of traffic lights is 20. These statistics sheds some light on the relationship among travel time saving, number of traffic lights, and diversion percent.

2.3 Modeling methodology

2.3.1 Cross-sectional model

In our SP survey, drivers’ response is binary choice in nature: drivers will either choose to divert to the arterial road or keep driving on the expressway. Thus, the binary logit model [33] is an appropriate modeling method for behavior analysis. It starts from an assumption that driver “ i ” makes decision based on one random utility function U_i^* , which can be parameterized as

$$U_i^* = \beta_0 + \mathbf{x}_i\boldsymbol{\beta} + \varepsilon_i. \quad (1)$$

In this equation, “ i ” is an index variable indicating each observation; \mathbf{x}_i is a row vector of explanatory variables of interest (e.g., travel time saving, number of traffic lights, and demographic characteristics); β_0 is a constant and $\boldsymbol{\beta}$ is a column vector of coefficients associated with the explanatory variables; and ε_i is a random variable that takes account of unspecified explanatory variables for U_i^* , which is assumed to be independently standard logistically distributed. If we specify y_i as a dummy variable indicating whether driver “ i ” will divert to the arterial road ($y_i = 1$, divert; $y_i = 0$, not divert), then the probability of observing y_i for each observation “ i ” is

$$P_i = \left[\frac{\exp(\beta_0 + \mathbf{x}_i\boldsymbol{\beta})}{1 + \exp(\beta_0 + \mathbf{x}_i\boldsymbol{\beta})} \right]^{y_i} \left[\frac{1}{1 + \exp(\beta_0 + \mathbf{x}_i\boldsymbol{\beta})} \right]^{1-y_i}. \quad (2)$$

2.3.2 Mixed logit model

As per Train [34], mixed logit model with random parameters can accommodate correlation of utilities of the same driver. In a mixed logit model, the utility function is formulated as

$$U_{it}^* = \mathbf{x}_{it}\boldsymbol{\beta} + \mathbf{z}_{it}\boldsymbol{\gamma}_i + \varepsilon_{it}. \quad (3)$$

In the utility function, “ i ” is the driver index and “ t ” is the scenario index; \mathbf{x}_{it} contains a vector of explanatory variables. \mathbf{x}_{it} may include some variables changing across drivers but not changing across scenarios (e.g., driver’s age and type). Those variables are called “individual variables” in this paper. The vector \mathbf{x}_{it} may also include some variables changing across scenarios but not changing across drivers (e.g., travel time saving, number of traffic lights). Those variables are called “scenario variables” in this paper. The vector \mathbf{x}_{it} also contains a constant “1” for the alternative specific constant in the utility function. “ ε_{it} ” is a random variable changing across both individuals and scenarios. It is assumed that “ ε_{it} ” is independently standard logistically distributed. In addition to a vector of variables \mathbf{x}_{it} and their constant coefficients $\boldsymbol{\beta}$, a vector of random coefficients $\boldsymbol{\gamma}_i$ are specified for a vector of variables \mathbf{z}_{it} in the utility function. The random coefficients $\boldsymbol{\gamma}_i$ vary across

drivers but do not vary across scenarios for the same driver. Assume that γ_i are independently normally distributed and associated with a vector of expectations γ and a vector of standard deviations σ_γ . Then, one may first obtain the probabilistic function conditional on random parameters γ_i as

$$P(y_{it} = 1|\gamma_i) = \frac{\exp(\mathbf{x}_{it}\boldsymbol{\beta} + \mathbf{z}_{it}\gamma_i)}{1 + \exp(\mathbf{x}_{it}\boldsymbol{\beta} + \mathbf{z}_{it}\gamma_i)}, \quad (4)$$

$$P(y_{it} = 0|\gamma_i) = \frac{1}{1 + \exp(\mathbf{x}_{it}\boldsymbol{\beta} + \mathbf{z}_{it}\gamma_i)}. \quad (5)$$

Here, y_{it} is a dummy variable indicating whether driver i will divert under scenario t ($y_{it} = 1$, divert; $y_{it} = 0$, not divert)

For an unconditional probabilistic function, the conditional probabilistic function needs to be integrated for all the scenarios over the probability density function of γ_i , $f(\gamma_i)$:

$$P_i = \int_{-\infty}^{+\infty} f(\gamma_i) \prod_{t=1}^T P(y_{it}|\gamma_i) d\gamma_i. \quad (6)$$

Here, T is the number of scenarios. The maximum simulated likelihood estimation method [35] can be employed to evaluate the integral.

The log-likelihood function for the entire sample can be formulated as

$$LL = \sum_{i=1}^N \ln(P_i). \quad (7)$$

Here, N is the number of observations. Then, the simulated log-likelihood function can be maximized for estimating all the model coefficients.

3 Model estimation results and discussion

3.1 Model estimation results

The model estimation procedure is executed via GAUSS 8.0 [36]. The explanatory variables tested for the cross-sectional binary logit model include age, age square, gender, years of driving experience, driver type, expressway use frequency, travel time saving, cause of expressway delay, and number of traffic lights on the arterial road. For the mixed logit model, travel time saving, and number of traffic lights are variables taking random parameters in the utility specification. It is one of the interests of this study to explore whether there exists heterogeneity regarding these two variables.

Table 2 provides model estimation results for the cross-sectional binary logit model and the mixed logit model. All the variables remaining in the final cross-sectional binary

logit model take statistically significant coefficients. The variables of statistical significance that enter the final cross-sectional binary logit include: (a) years of driving experience; (b) the dummy variable indicating driver seldom using expressway; (c) the dummy variable indicating driver using expressway every day; (d) the dummy variable indicating employer-provided car driver; (e) age and age square; (f) number of traffic lights on the arterial road (l); and (g) travel time saving (s).

Other attribute variables such as gender and cause of expressway delay do not obtain coefficient of statistical significance in the cross-sectional binary logit model.

3.2 Discussions about VMS impacts

Discussions of the coefficients of the final cross-sectional model are presented below.

3.2.1 Driving experience

Driving experience plays a positive role in diversion decision under VMS as shown by the positive coefficient of “years of driving experience.” This is probably because drivers with rich-driving experience are more adaptable to expressway delays and more familiar with local streets and thereby more likely to divert in response to VMS. Drivers with less-driving experience may not feel comfortable with diversion-related vehicle operating such as finding an available inserting gap and making a lane change in dense traffic.

3.2.2 Expressway use frequency

The positive coefficient of “use expressway seldom” and the negative coefficient of “use expressway everyday” indicate that the increase of expressway use frequency decreases the probability of diverting to the alternate arterial road route under VMS. It is probably because drivers using expressways frequently have a big dependence on or a bias for expressways. Interestingly, similar findings were obtained in some earlier studies, e.g., [37, 38].

3.2.3 Driver type

Interestingly, employer-provided car drivers are less likely to divert in response to VMS, as indicated by the negative coefficient of the dummy “employer-provided car.” This finding has implications for design and assessment of VMS systems since employer-provided cars represent a significant percentage of traffic in many Chinese cities (e.g., 5 %–20 % in Shanghai). Moreover, this finding coincides with the author’s earlier study which found that employer-

Table 2 Estimation results of two alternative logit models

Variable	Cross-sectional model		<i>p</i> value	Mixed logit model		<i>p</i> value
	Coefficient	<i>T</i> test		Coefficient	<i>T</i> test	
Constant	3.2646	2.356	0.018	4.9583	1.447	0.148
Driving experience	0.0329	1.977	0.048	0.0358	0.870	0.384
Use expressway seldom	0.3659	1.944	0.052	0.2473	0.537	0.591
Use expressway everyday	−0.8287	−5.070	0.000	−1.4441	−3.507	0.000
Employer-provided car	−0.5928	−4.034	0.000	−0.9869	−2.713	0.007
Age	−0.2154	−2.954	0.003	−0.2928	−1.614	0.107
Age square/100	0.2934	3.041	0.002	0.3883	1.626	0.104
Number of traffic lights (<i>l</i>)	−0.0931	−6.916	0.000	−0.1436	−7.107	0.000
Travel time savings (<i>s</i>)	0.2738	10.083	0.000	0.4027	9.684	0.000
Standard deviation of coefficient for <i>l</i>	–	–		0.094	5.21	
Standard deviation of coefficient for <i>s</i>	–	–		0.1706	5.16	
Maximum log likelihood	−662.13			−595.39		
Log likelihood only with constant	−774.72			−774.72		
Adjusted goodness-of-fit index	0.1350			0.2186		

provided cars are less likely to divert from expressway to arterial roads in response to VMS displaying a color-coded level of service map [16].

3.2.4 Age

The specification of age and quadratic term of age is to quantify the potential non-linear effect of age on diversion behavior. This kind of specification is often used in social sciences (e.g., [39]). “Age” and “age square” receive negative and positive coefficients, respectively, indicating that young and old drivers are more likely to divert under VMS, while middle-aged drivers are less likely to divert. Based on estimation results of the cross-sectional model, mid-age drivers, at the age of 37 (i.e., $[0.2154/(0.29349 \times 2)] \times 1 \approx 37$), are the least likely to divert.

3.2.5 Number of traffic lights

Negative effects of number of traffic lights on drivers’ diversion are reflected in the negative coefficient of “number of traffic lights on the alternate route.” This result is reasonable since more traffic lights on the alternate route means more frequent stops and a lower comfort level of driving and will naturally decrease the probability of diverting to the a driver to on the alternate route under VMS. This finding coincides with some previous studies (e.g., [5]).

3.2.6 Travel time saving

Travel time saving measures how much travel time drivers can save through diverting to the local street. The positive

effects of travel time saving on diversion behavior are evidenced by the positive coefficient of “travel time saving.” This indicates that explicitly displaying the travel time of the expressway, and the arterial road alternate route by VMS is meaningful and will positively influence drivers’ diversion decision behavior.

3.3 Discussions about heterogeneity

The second block of Table 2 lists the model estimation results for the mixed logit model in which random coefficients are specified to accommodate heterogeneity in driver behavior and correlation of repeated choices by the same driver. Two random coefficients are specified for two scenario variables: time saving and number of traffic lights.

The standard deviation of the random coefficient for travel time savings is estimated at 0.1706 and appears highly significant (*t* value 5.16). This evidences that the random coefficient for travel time savings is not a constant but a variable varying among the driver population. This indicates that there exist random preferences for “travel time saving” across the driver population. This actually reveals the heterogeneity in value of time among the driver population. For the specific VMS information addressed by this study, this finding shows that although the travel time saving (as indicated by estimated travel time for the expressway route and the arterial road route) basically has a positive role in encouraging drivers to divert from the expressway to the local street, the value of travel time information is perceived differently by different people. For example, drivers under time pressure to get to a meeting on time will more value the travel time saving than

those not having such time restrictions. For these drivers, the coefficient of the variable travel time saving should be larger than other drivers, i.e., being more sensitive to travel time savings indicated by VMS. In reality it is also possible that some people just have a preference for expressways or it is just a routine (inertia) for them to choose expressways; thus for these people the coefficient of the variable travel time saving should be relatively small, i.e., being less sensitive to travel time savings.

The standard deviation of the random coefficient for number of traffic lights is estimated at 0.0940 and appears highly significant (t value 5.21). The estimation result evidences that the coefficient for number of traffic lights is not a constant but a variable varying among the driver population. This indicates that there exists a significant degree of heterogeneity in the perception of the negative impacts of number of traffic lights. This reflects the real Shanghai situation. In Shanghai, most urban expressways are elevated roads and their competitive alternate routes are the parallel arterial roads under them. Under normal traffic conditions, an elevated road usually has much shorter travel time than an alternate arterial road route. The superiority of an elevated road is due to the fact that the elevated road typically has a good geometrical alignment and has a higher free-flow speed without intersections while the arterial road typically has a not so good geometrical alignment, has many signal-controlled intersections, and often has abrupt (unreasonable) changes in road markings which may affect the comfort of driving and cause delays. Given these facts, many less-experienced drivers are likely to not feel comfortable with the arterial road that has many traffic lights and prefer to use the elevated road even when VMS indicates the arterial road is faster. Yet, drivers with rich driving experience may be more confident of their ability of manipulating vehicles on the arterial road and are more adaptable to expressway delays and more willing to divert to the arterial road under VMS.

The above estimation results show that the developed mixed logit model can be successfully applied to model our SP panel data in which correlation of random utilities for the same driver needs to be accommodated. As a result, all the t test values of coefficients for the individual variables are smaller in the mixed logit model than those in the cross-sectional logit model. Comparison of adjusted ρ^2 values between the mixed logit model and the cross-sectional model suggests that the mixed logit model performs obviously better than the cross-sectional model (0.2186 vs. 0.1350).

4 Concluding remarks

A conventional cross-sectional logit model and a mixed logit model are developed to model drivers' decision

behavior under Shanghai's new expressway VMS information which provides travel time of an expressway and an alternate arterial road route. This is based on the data collected from the SP survey that explores drivers' diversion response to the new expressway VMS information. The mixed logit model has a utility specification that accounts for preference variations across individuals regarding travel time and number of traffic lights and correlations among repeated choices. Several substantive conclusions have been obtained in this study as summarized below.

- (1) The new expressway VMS information service has significant impacts on driver diversion decisions. Travel time saving and driving experience serve as positive factors, while the number of traffic lights on the arterial road, expressway use frequency, being a middle-aged driver, and being a driver of an employer-provided car serve as negative factors in diversion.
- (2) There exists an obvious heterogeneity in value of travel time among the driver population, as evidenced by the significance of the standard deviation of the random coefficient for travel time saving in the mixed logit model.
- (3) There exists an obvious heterogeneity in the perceived importance of "number of traffic lights" among the driver population as evidenced by the significance of the standard deviation of the random coefficient for number of traffic lights in the mixed logit model.
- (4) The mixed logit model is successfully applied to model our SP panel data in which correlation of random utilities for the same driver needs to be accommodated, which is indicated by the fact that the mixed logit model obviously outperforms the conventional cross-sectional logit model regarding the goodness-of-fit criterion.

This study highlights the importance of capturing the heterogeneity of driver preferences and recognizing potential correlations between the individual's choices using appropriate modeling techniques such as the mixed logit model used in this study.

The estimated route choice probability model may be incorporated within a dynamic traffic assignment and simulation framework to assess network-level impacts of the enhanced expressway VMS information and estimate VMS benefits.

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